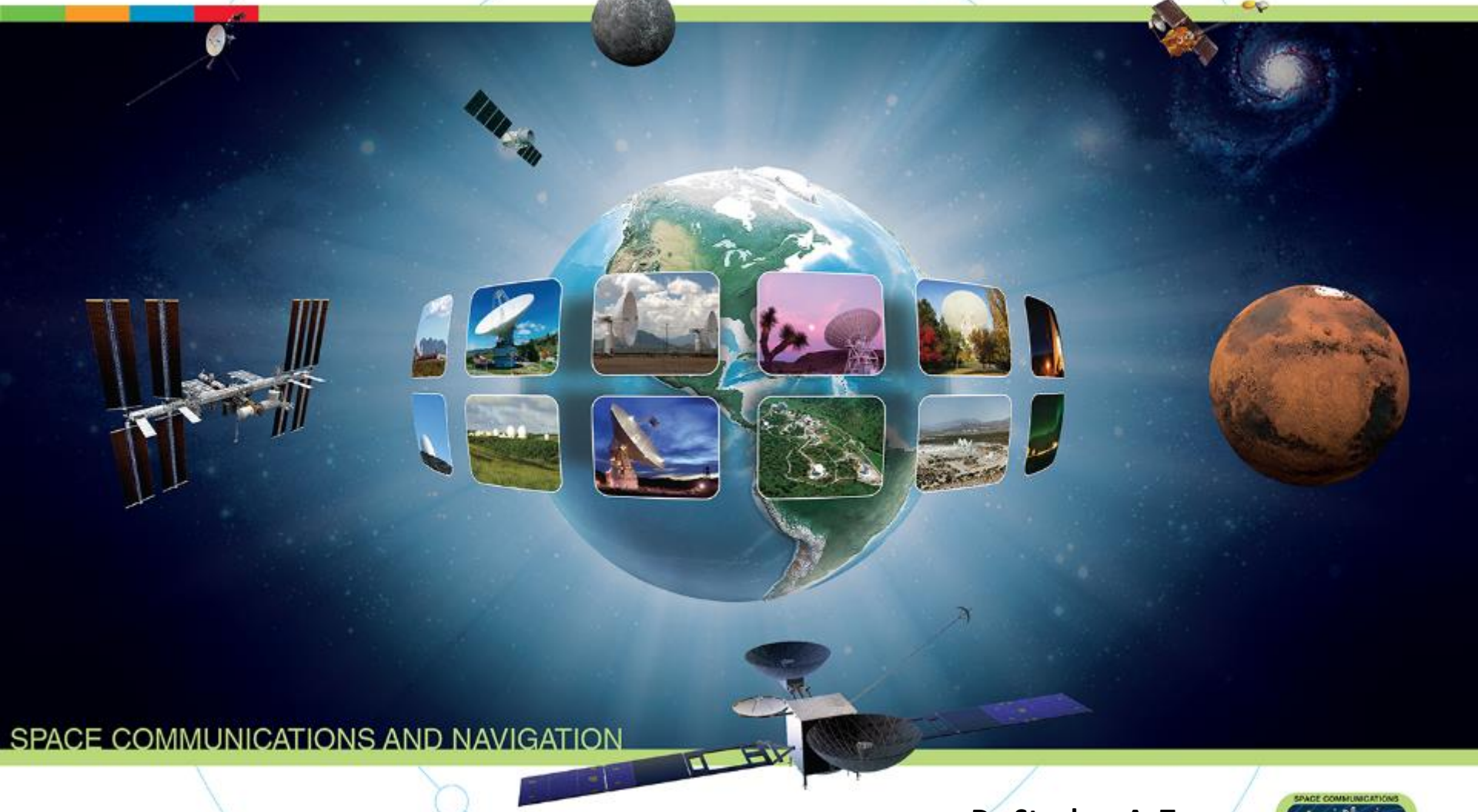
Thoughts on Free Space Optical Communication and Standards for Space Applications



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www.nasa.gov

Why Laser Communication?

- Narrower beamwidth than RF for equivalent aperture
  - Brings the complexity of pointing narrow beams
- Potential for improved size, weight, and power (SWAP) metrics due to smaller components possible with smaller wavelengths
  - Maturation of components—particularly power efficiency
- Security—narrower beamwidth means smaller area of intercept
- Currently no spectrum limitation or regulation
  - High data rates

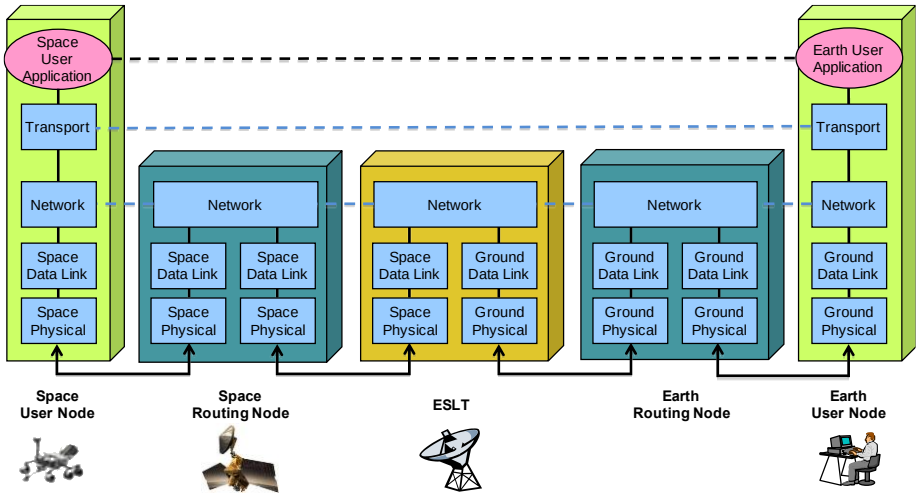
Factors for Consideration

- Link scenarios/applications (see following charts)
  - Space-to-Space, Space-to-Earth, Multi-hop, etc.—free space, turbulence/no turbulence, clouds/no clouds, atmosphere/no atmosphere, Sun, …
  - Robotic Science or Human Exploration--differences in reliability, latency, etc.
  - Big infrastructure or low cost
  - Resource constraints—size, weight and power (SWAP) or funds
- Implementation
  - Frequency/Wavelength(s)
  - Pointing, Acquisition and Tracking
  - Modulation
  - Error control: ARQ, channel coding, interleaving, etc.
  - Channel rate variation to account for impairments or less capable links
  - Data link layer interface
  - Physical layer framing
- Interfaces to other networks—end-to-end considerations, gateway conversion, etc.
- Leveraging of Existing standards (e.g., CCSDS, ITU-T, ETSI, IETF, etc.)
- Interoperability agreements

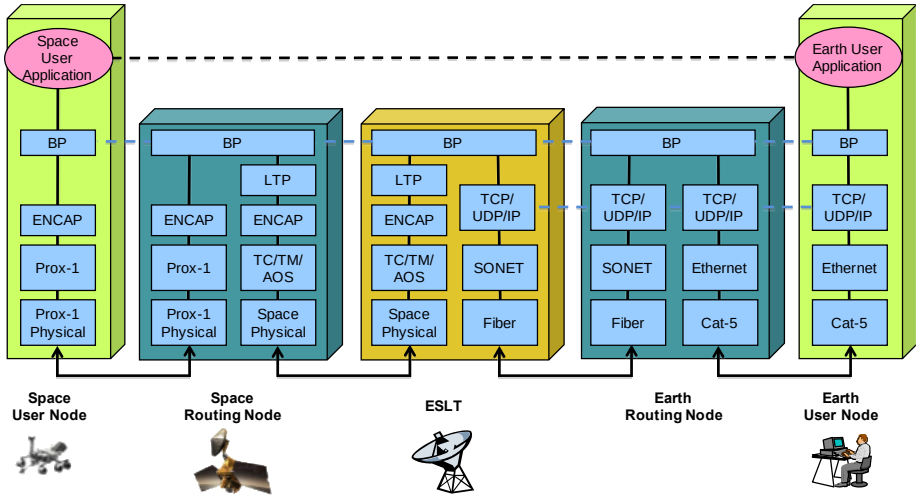
Layers and Stacks

OSI Model			
Layer		Protocol Data Unit (PDU)	Function
Host Layers	7. Application	Data	High-Level APIs, including resource sharing,
	6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5. Session		Managing communication sessions, i.e., continuous exchange of information in the form of multiple back-and-forth transmissions
	4. Transport	Segment (TCP)/Datagram (UDP)	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media Layers	3. Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2. Data Link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1. Physical	Bit	Transmission of raw bit streams over a physical

https://en.wikipedia.org/wiki/OSI_model

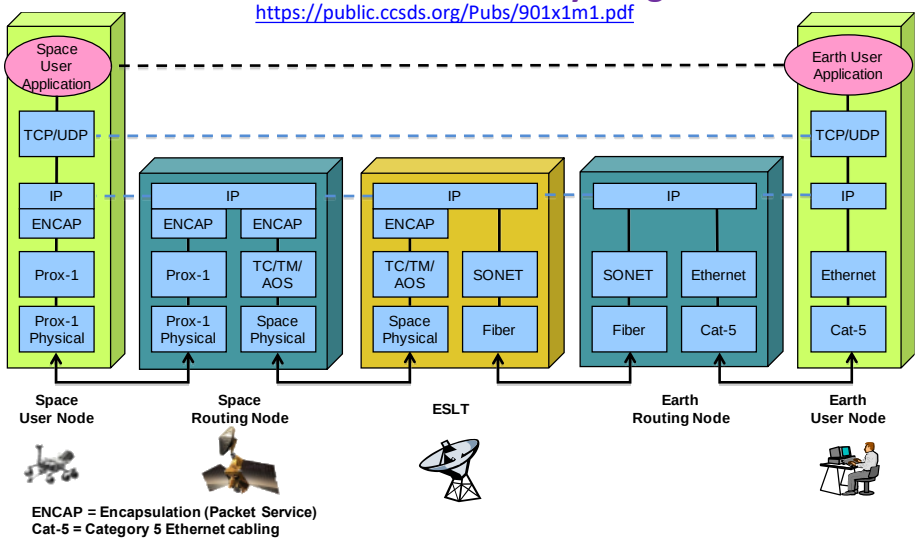


7-Layer Model



Basic SSI Protocol Layering

https://public.ccsds.org/Pubs/901x1m1.pdf



Protocol Layering for BP-based SSI Communications

Protocol Layering for IP-based SSI Communications

Standards Bodies

- Consultative Committee for Space Data Standards (CCSDS)
- European Standards Organization (ESO)
  - European Telecommunications Standards Institute (ETSI)
- International Telecommunication Union Telecommunication Standardization Sector (ITU-T)
- Internet Engineering Task Force (IETF)

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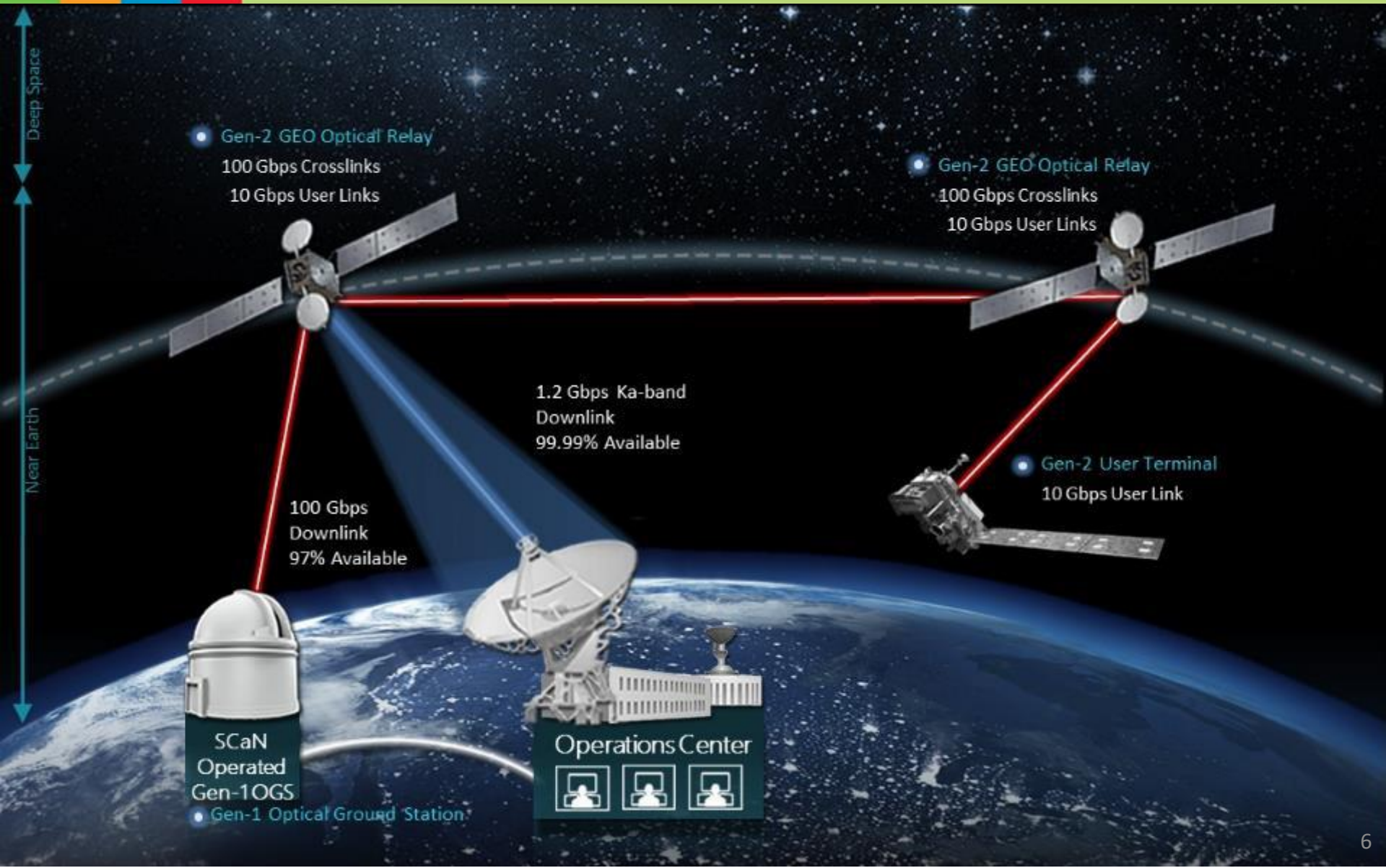
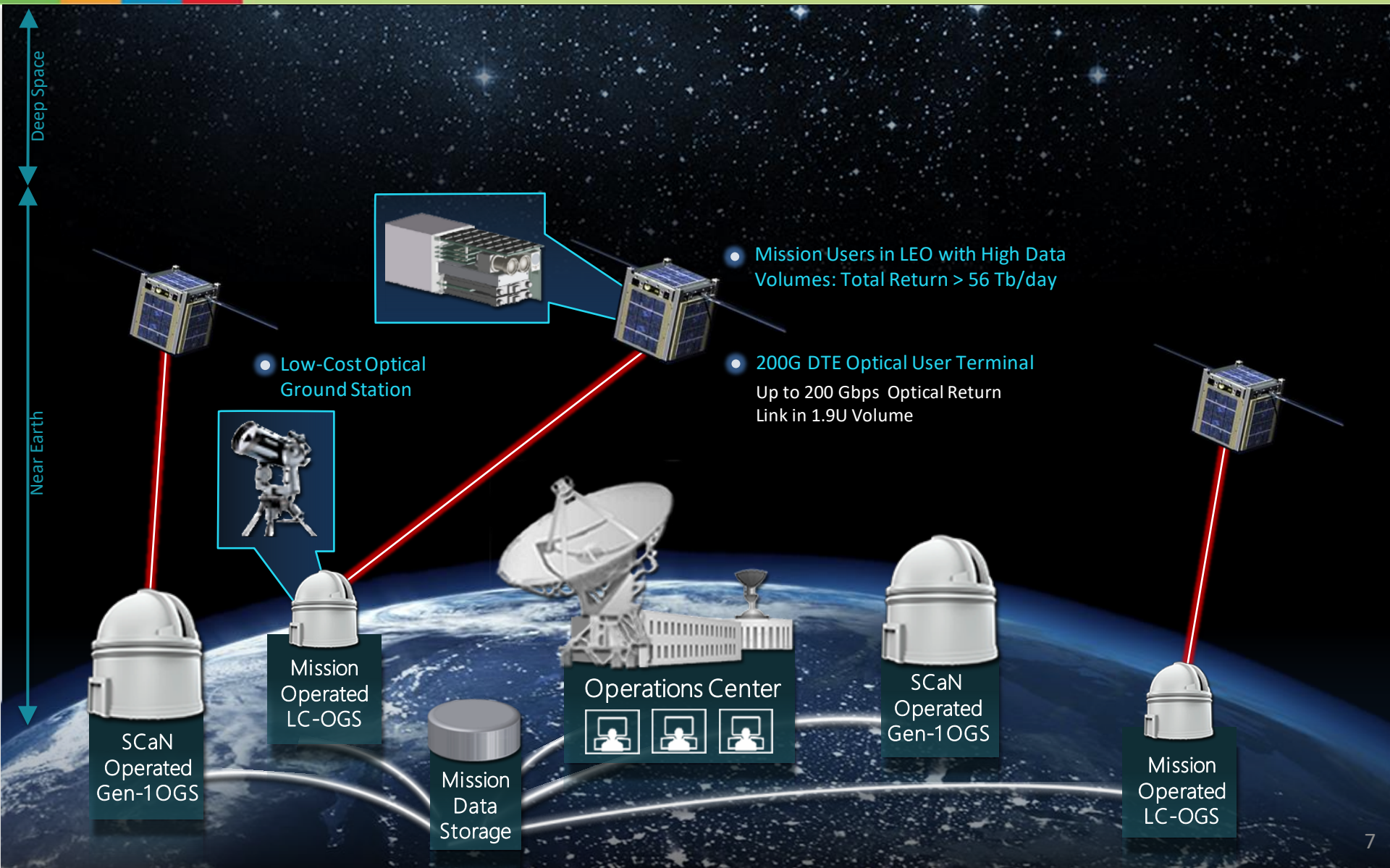
Too many to list, see https://en.wikipedia.org/wiki/List_of_technical_standard_organisations

NASA's Planned Next Gen Relay (2024) with 10G Users and 100G Crosslinks



NASA's Optical Plan Forward: Ultra-High Data Rate LEO Direct-to-Earth (DTE)



NASA's Optical Plan Forward: Deep Space Optical Communications

Deep Space

Near Earth

Planned Psyche Demo

DSOC Gen-1 Optical User Terminal

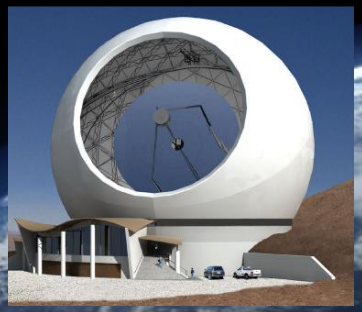
DSOC on Psyche Asteroid Mission 2023
125 Mbps from 40M km

And beyond …

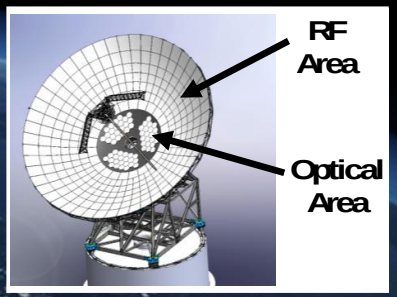
DSOC Gen-1 Optical Ground Station

DSOC Gen-1OGS

Operations Center



New Build—12 m Segmented Spherical Primary



Hybrid RF-Optical 34 m Antenna

Questions?

BACKUP

WG Charter

Working Group 6: Space Technologies

Laser Space Communications

Laser communications, also known as optical communications, are believed to be one of the latest game changing space technologies. Laser communications would be able to provide data rates of as much as a hundred times higher than current systems. NASA SCaN and its partners are working to revolutionise the way astronauts communicate to and from space using an advanced laser communications system called LEMNOS, which will enable exponentially faster connections than ever before. NASA has already conducted the Lunar Laser Communications Demonstration (LLCD) in 2013, and is planning to launch the Laser Communications Relay Demonstration (LCRD) to geostationary orbit in 2019, followed by the Deep Space Optical Communications terminal on the Discovery Psyche mission in 2022. This working group will explore common standards to enable interoperability between laser communication systems.

This working group will face the following questions:

- 1) Brainstorm about the wide range of Link scenarios/applications for this exciting new laser communications technology.
- 2) Consider the challenges in finding a “common” interoperable FSOC mode—akin to the International Telecommunication Union Optical Transport Network (OTN) standard agreed to by the ground based fiber telecommunications industry.
- 3) Provide recommendations about how to achieve a common industry position on FSOC system interoperability to enable the level of cross support required by international space agencies (Interoperability agreements/ Leveraging of Existing standards (e.g., OTN, DVB-S2), Interface Control Documents (ICDs)).